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Evaluation of Nutrient Leaching in Pots under Greenhouse Condition

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Abstract

The use of fertilizers in agriculture is a possible source of soil and water pollution. The aim of the study was to evaluate leaching of N, Ca and Mg in a pot experiment under two fertilizers rates, in the presence and absence of plants and with two different soil types (loamy and clay loam soil). Half of the pots were planted with Italian ryegrass (*Lolium multiflorum*) in order to evaluate effect of the presence of the plants on the leaching process. Results show a relatively high amount of N and Ca leached especially from the loamy soil and in absence of the plants. The presence of ryegrass plants decreased the amount of N and Ca leached significantly. Mg was leached in smaller amounts compared with the other two elements.

Keywords: Nitrogen, calcium, magnesium, leaching, reygrass pots.

1. Introduction

Agriculture plays an important role in environmental pollution, related mainly to the leaching of different nutrient elements in water receiving body. The application of fertilizers to the agricultural fields can contribute to the contamination of the surface and groundwater through different routes including, runoff directly to drainage streams and percolation to the groundwater. Excess amount of such elements can be leached through the soil profile and can emerge in the water bodies. Elevated nutrient concentrations in surface waters contribute to the eutrophication process, disrupting ecosystem processes as well as harming aquatic communities [3]. The extent of nutrient leaching from the agricultural soils depends on the climate characteristics, soil type [10, 16, 21], quantity of nutrients in the soil [22], agricultural practices [8], and of course of the nutrients characteristic [14].

Nitrogen is the most mobile macronutrient in the soil solution. In the nutrient solution it is found in two mineral forms as nitrate and ammonium. Nitrate is the main form of mineral nitrogen present in the agricultural soils. Its concentrations in the soil solution may rise rapidly not only through fertilization but also through transformations of the nitrogen present in the soil organic matter. Nitrate leaching depends mainly on the amount of water in the soil, cultivation techniques, as well as the uptake rate from the plants cultivated [13]. Ammonium, which is the second mineral form in which nitrogen is found in the soil solution, is less leachable, since it can be retained in the interlayer's of the 2:1 clay minerals [20]. Former studies have shown that only 30 to 50% of the N applied in fertilizers is used by the crops [4, 23], and the rest can be leached contributing to the pollution of groundwater [3] or lost in the atmosphere in form of ammonia, molecular nitrogen or nitrogen oxides contributing to the increase of the greenhouse gasses [14].

Calcium is also one of the elements that can be leached from agricultural soils in high amounts [12, 14]. Ca leaching is high in soils where the Ca concentration in the soil solution is high and it is increased from high rainfall amounts and H^+ release in the soil. Also cation competition especially between Calcium and Magnesium and Potassium plays an important role in Ca availability in the soil solution and consequently in its leaching potential. Earlier studies show that leaching under maize cultivation can reach values over 140 kg ha^{-1} $year^{-1}$ Ca [15]. Experiments conducted in forest soils have shown relatively large differences in Ca leaching depending on the soil conditions rainfall amount and forest

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species [6, 9]. In long term perspective calcium leaching can induce a pH reduction especially when correlated with proton influx in the soil [14].

Magnesium concentration in most soils lies generally between 0.5 g kg^{-1} for sandy soils and 5 g kg^{-1} for clay soils [19]. Due to its thicker water mantel, Mg ions are absorbed less tightly to the soil colloids and therefore can be easily leached than Ca ions. Lysimeter experiments have shown that up to 29% of the added Mg through fertilization was leached under maize cultivation. This amount increased significantly under no cropping conditions [24].

2. Materials and Methods

In order to estimate the nutrient leaching, the experiment was conducted in 32 pots each 30 cm high and 25 cm in diameter at the greenhouse of the Faculty of Agriculture and Environment, for the period 2014-2015. The experiment comprised different 8 treatments: two different soil types, two different fertilization rates, with and without vegetation.

The soils used were selected with different amounts of sand and clay particles. The first soil was a loamy soil with almost 46% sand and 8% of clay, and the second soil was a clay loam soil with 28% clay (Table 1).

Table 1. Physical characteristics of the soils used in the experiment.

Soil	Sand (%)	Silt (%)	Clay (%)
1	46	46	8
2	24	48	28

The pH values ob both soils didn't show differences between the two soils, whereas the amount of Nmin, was higher in the clay loam soil (soil Nr 2) compared with the loamy soil (Table 2).

Table 2. Chemical characteristics of the soils used in the experiment.

Soil	pH	Total N (%)	NH_4^+ (mg kg^{-1})	NO_3^- (mg kg^{-1})	P (mg kg^{-1})	K (mg kg^{-1})	Mg (mg kg^{-1})	Ca (mg kg^{-1})
1	7.68	0.06	14	11	8.41	211	52.64	3650
2	7.69	0.128	14	28	13.36	176	63.17	4180

In 22 September 2014 the half of the containers were planted with Italian ryegrass (*Lolium multiflorumItalicum?*) in order to evaluate the leaching of the nutrients in the presence and in the absence of crops. Italian ryegrass was selected as a plant with a rapid growth and with a high amount of nutrient uptake.

In the two fertilizers treatments pots received the equivalent amounts of: nutrients

First treatment: 50 kg*ha^{-1} N, 150 kg*ha^{-1} K, 50 kg*ha^{-1} P, 100 kg*ha^{-1} Ca and 100 kg*ha^{-1} Mg.

Second treatment: 100 kg*ha^{-1} N, 300 kg*ha^{-1} K, 100 kg*ha^{-1} P, 200 kg*ha^{-1} Ca and 200 kg*ha^{-1} Mg.

The nutrients were used in the following forms: N as NH_4NO_3, K as K_2SO_4; P as single superphosphate and Mg as kieserite ($MgSO_4$ H_2O; 17%). The total amount of nutrients was divided in two fertilization rates. The first five days after full emergence of the ryegrass plants and the second after the first cut.

All pots were irrigated with an equivalent amount of water simulating the rainfall in winter time in the western lowland in Albania.

Drained water was collected after each irrigation event from each container and was stored in plastic bottles in the refrigerator at a temperature of 4°C. All the collected water samples were transferred at the laboratory of the Institute of Food Safety and Veterinary in Tirana, where they were analysed for the main elements

After each cutting the plant material was air dried for 48 hours weighted and analyzed for the main nutrient elements.

Figure 1: Photo of the experiment in the greenhouse.

3. Results and Discussion

The total uptake of nitrogen, calcium and magnesium from the ryegrass plants has been influenced from the fertilization rates and from the soil type as well. The data (Table 4) show an increase of the dry matter accumulation of the ryegrass plants with the increase of the fertilizers rate. If we have a look at the nutrient concentration of the two soils used in the experiment, it can be noticed that the clay loam soil posses a higher production potential compared with the loamy soil (Table 2). This potential has been used by the ryegrass plants that were able to produce 45-50 % more dry matter in the plots filled with clay loam soil, compared with the one filled with loamy soil (Table 3).

Table 3. Total Dry Matter and Nitrogen, Calcium and Magnesium uptake from ryegrass plants in both cuts. (Different letters represent statistical significant differences between the treatments).

Treatments	Dry Weight (T ha^{-1})	Uptake (kg ha^{-1})		
		N	Ca	Mg
Loamy Soil 50% Fertilizer	4.671(A)	38.31	15.79	8.41
Loamy Soil 100% Fertilizer	5.841(B)	66.32	23.33	13.60
Clay Loam Soil 50% Fertilizer	6.810(C)	58.42	24.03	11.89
Clay Loam Soil100% Fertilizer	8.733(D)	104.77	37.44	21.63

The amount of nitrogen leached in the loamy soil fluctuated between 31 kg ha^{-1} (treatment 50% of fertilizers with plant presence) and almost 85 kg*ha^{-1} (treatment 100% fertilization without plants) (Figure 2a). In the clay loamy soil the amounts of nitrogen leached was much lower than in the loamy soils reaching a maximum of 36 kg*ha^{-1} in the treatment 100% fertilization without the presence of the plants. (Figure 2.b). These figures are somewhat higher than the one reported from Beaudoin et al. [1], but were almost in the same range with the values recorded from Riley et al. [17] in soils with almost the same soil texture.

Due to their high Relative Growth Rate, and to the very dense root system, ryegrass plants are able to take up in a short time relatively large amounts of nutrients especially nitrogen. As a consequence, the presence of the plants has reduced considerably nitrogen leaching in both soils and (Figure 2 a and b). This should be due to the relatively high amount of nitrogen accumulated by the plants. Similar achievements are reported earlier by other researchers working with different crops [5, 18].

The relatively high amounts on nitrogen that are leached in both soils don't derive only from the fertilization N, but, especially in the treatments with plants, also from the soil borne mineral N present in the soil since the beginning of the experiment as well as the mineralization of the organic N during the experimental period. Adding to the total amount of N taken up by the plants, the amount of N leached, we achieve higher values than the N amounts used during fertilization.

As expected, calcium and magnesium are leached in much smaller rates than nitrogen. For both nutrient elements the same tendencies as for nitrogen can be noticed. In the loamy soil the increase of the fertilization rate has caused a significant increase of the amount leached for both elements, whereas the plant presence has decreased considerably the values of Ca and Mg leached. The total amounts of Ca leached are much higher than those of Mg, which should be attributed to the much higher amounts of Ca compared to Mg in the soil at the beginning of the experiment. Di and Cameron [5] report, in a grassland mixture of *Lolium perenne* and *Trifolium repens*, for leaching amounts of more than 200 kg Ca ha^{-1} and almost 20 kg Mg ha^{-1} whereas Gilamn et al. [7] found higher amounts of Ca moved in the first 30 cm depth in an oxisol. In a lysimeter experiment Lehmann et al [11] registered leaching of Ca between 10 and 40 kg ha^{-1} and leaching amounts of Mg between 2 and 15 kg ha^{-1} during 38 days duration of the experiment under application of different fertilizers. Similar results were realized previously by other researchers [2].

In the clay loamy soil the differences between the planted and the not planted treatments are lower than in the loamy soil especially for Mg where these differences are not statistically significant. The non significant effect of ryegrass plants, in reducing Mg leaching in clay loamy soils, should come due to the higher retention capacity of the soil as well as due to the small Mg amounts taken up from the plants.

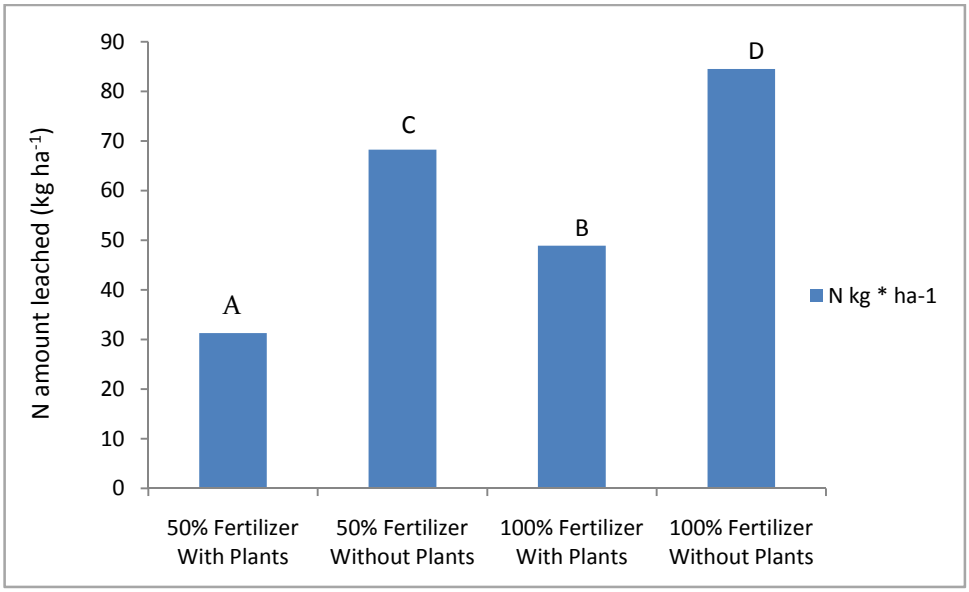

Figure 2 (a). Nitrogen leaching from the loamy soil.

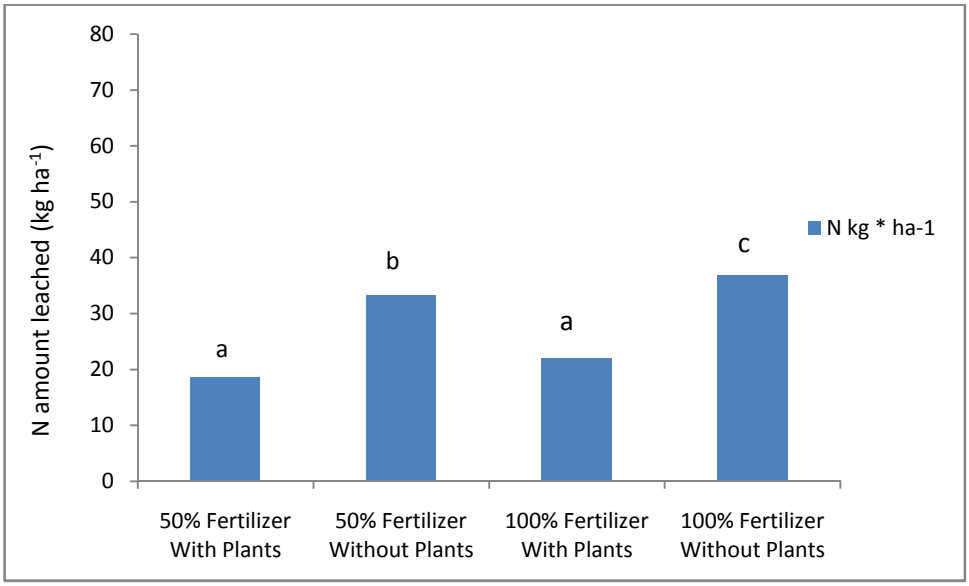

Figure 2 (b). Nitrogen leaching from the clay loamy soil.

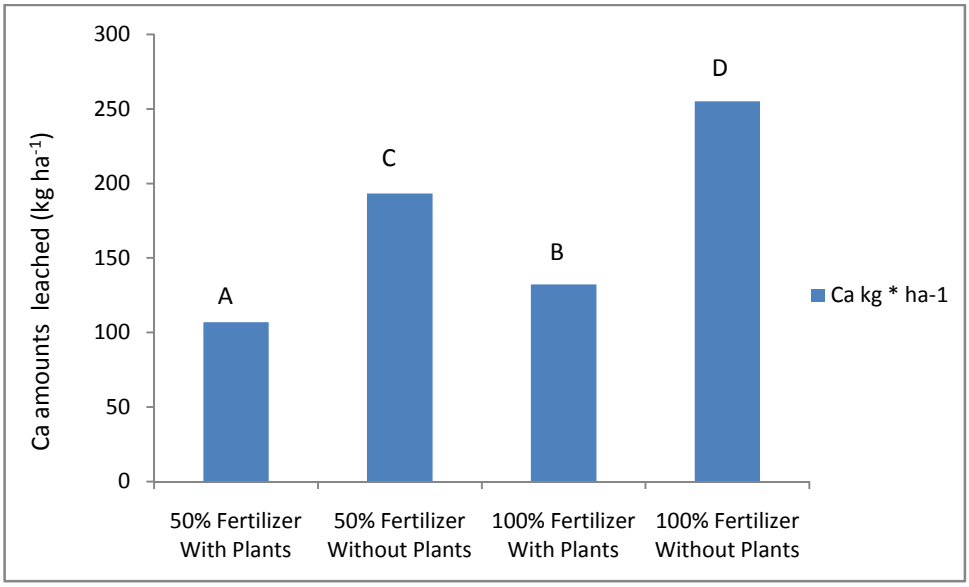

Figure 3 (a). Calcium leaching from the loamy soil.

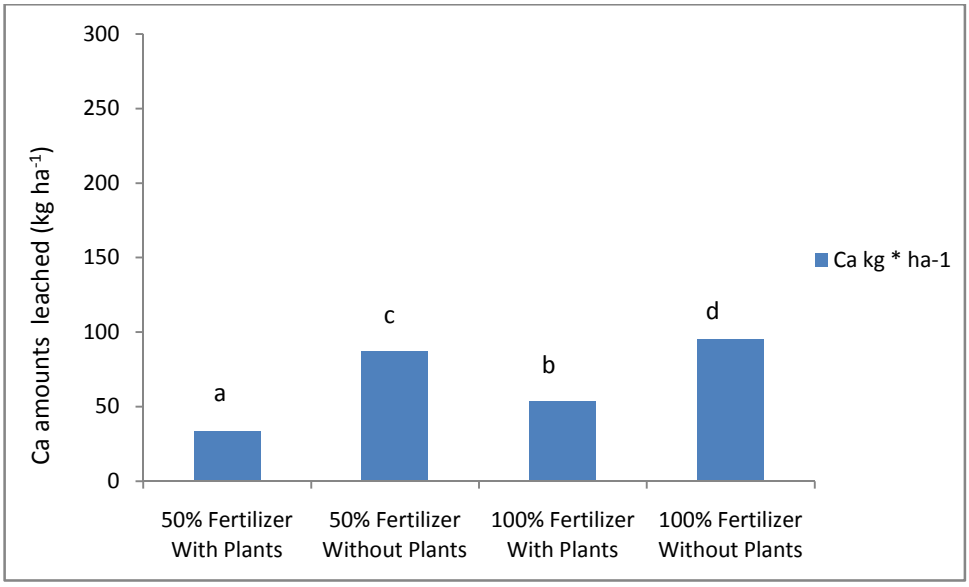

Figure 3 (b). Calcium leaching from the clay loamy soil.

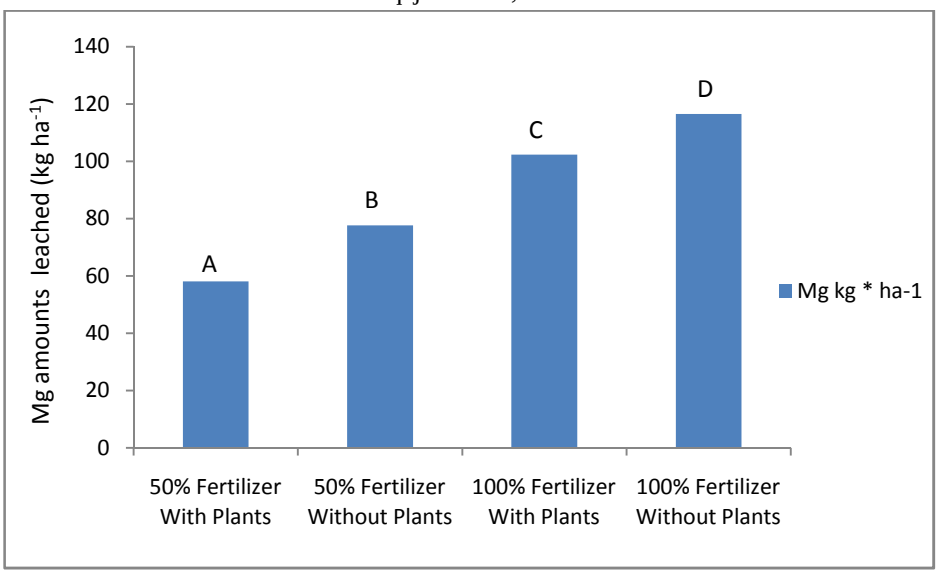

Figure 4 (a). Magnesium leaching from the loamy soil.

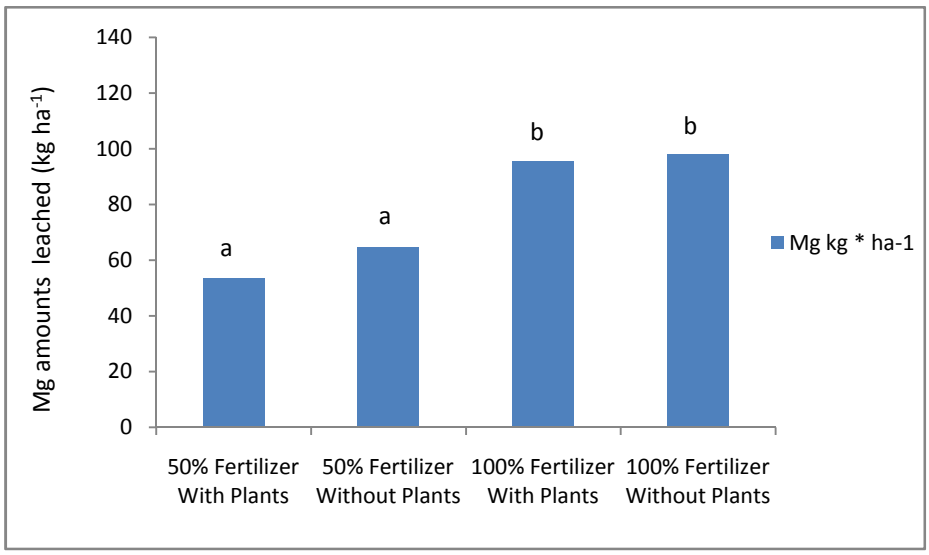

Figure 4 (b). Magnesium leaching from the clay loamy soil.

4. Conclusions

- Nitrogen and calcium were leached in higher amounts compared to magnesium.
- The N amounts leached can cause N deficiency in the agricultural soils, and represent a real pollution risk for groundwater.
- Ryegrass plant presence reduced nitrogen leaching especially by nitrogen in both soil types.
- Leaching of all the three nutrients were higher in the loamy soil than in the clay loamy soil.

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